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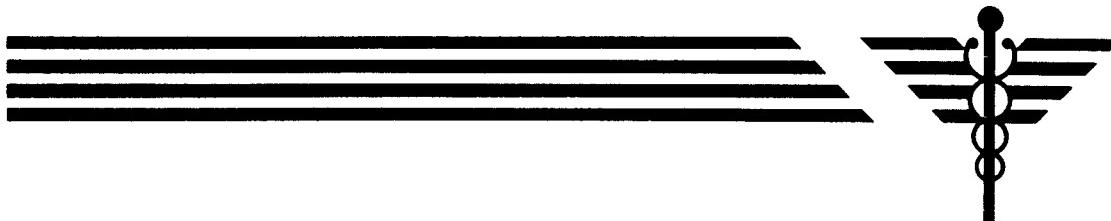
FORT KNOX, KENTUCKY

Report No. 108

10 January 1953

ROENTGENOLOGICAL BONE CHANGES ENCOUNTERED IN FROSTBITE - KOREA 1950-51*

*Subtask under Environmental Physiology, AMRL Project No. 6-64-12-028, Subtask Cold Injury Studies.



MEDICAL RESEARCH AND DEVELOPMENT BOARD
OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY

REPORT NO. 108

ROENTGENOLOGICAL BONE CHANGES ENCOUNTERED
IN FROSTBITE - KOREA 1950-51*

by

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ABSTRACT

ROENTGENOLOGICAL BONE CHANGES ENCOUNTERED IN FROSTBITE - KOREA, 1950-51

OBJECT

To identify and classify any changes produced in bone by cold or in relation to cold injury (frostbite).

RESULTS AND CONCLUSION

A group classification of bone changes produced by frostbite was devised as follows:

1. Group A showing osteoporosis.
2. Group B showing acromutilation (mutilation of terminal phalanges due to exposed bone).
3. Group C showing juxta articular areas of decreased density.
4. Group D showing other bone changes (i. e. periostitis, new bone formation and osteomyelitis).

The most common bone abnormality was that of osteoporosis. This finding plus the one of periostitis are useful indicators of the viability of the underlying bone pointing to an intact circulation and metabolism. The absence of osteoporosis in phalanges while being present in metatarsal and tarsal bones is suggestive of alteration or absence of circulation in the involved phalanges.

The late bone changes (Group C) are of particular interest. With two exceptions the changes were not noticed until 8 months post-frostbite. These changes are similar to those found at times in rheumatoid and degenerative arthritis. There was no correlation between the degree of soft tissue injury and roentgenological bone changes.

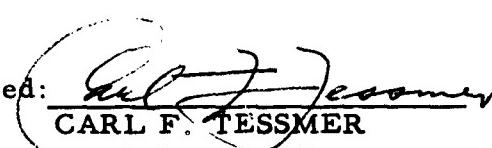
RECOMMENDATIONS

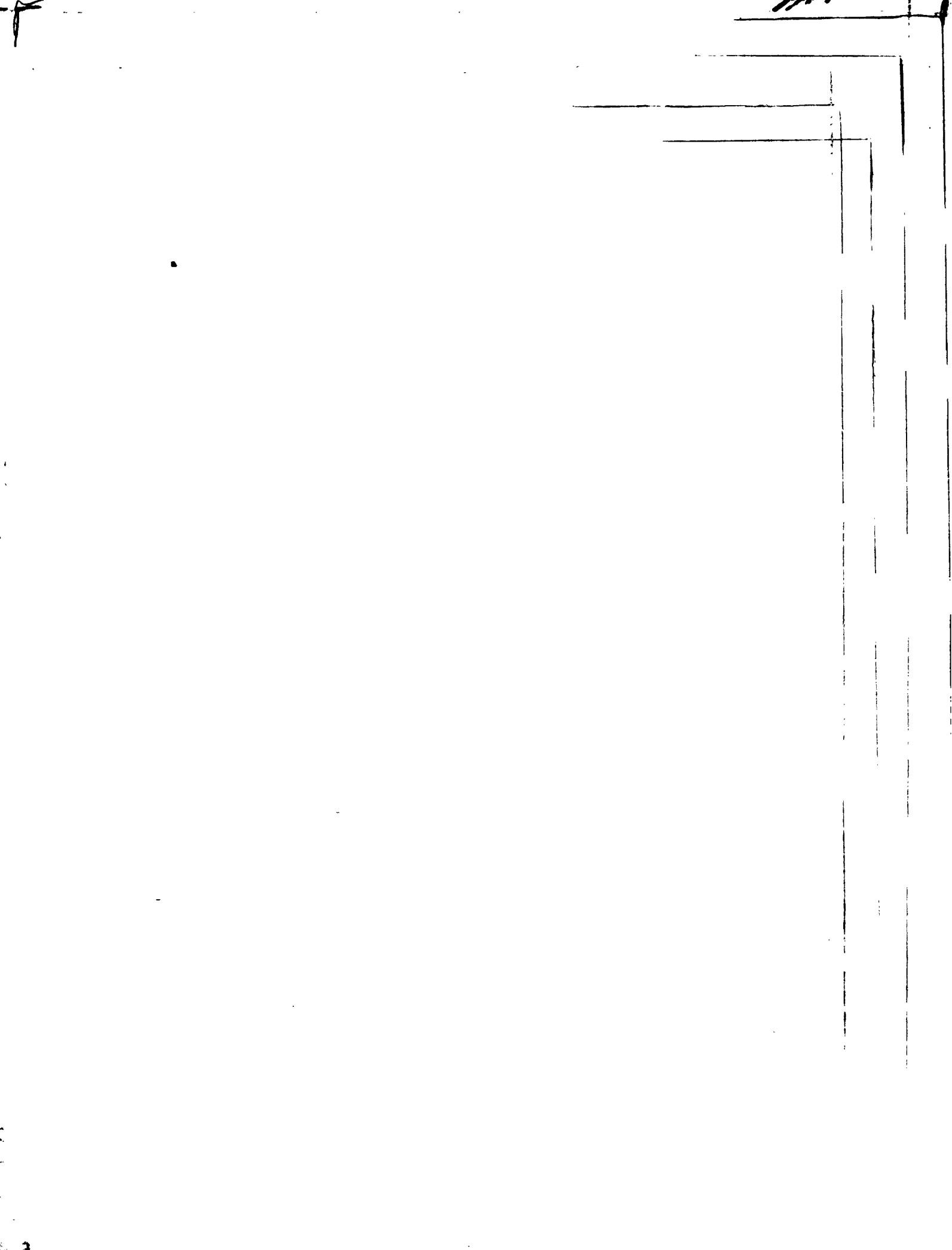
Followup studies should be performed on the 1950-51 study group of frostbite casualties (100 soldiers) for a period of 3 to 5 years.

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ROENTGENOLOGICAL BONE CHANGES ENCOUNTERED IN FROSTBITE - KOREA 1950-51

I. INTRODUCTION

The study of frostbite usually is centered on the damage of soft tissues. Changes which might occur in the underlying bone have been mentioned sporadically in a number of publications, almost exclusively from continental Europe (2, 3, 4, 5, 7, 8, 9, 10). These publications have concerned themselves primarily with the description of the atrophy supposedly occurring in bone following cold injuries. Occasional instances of calcifying periostitis and rare joint changes are mentioned (2, 5, 7, 9). In a recent article, Edwards and Leeper (1) mention bone lesions briefly. Systematic studies on the bone changes following frostbite in a large well controlled group have not been reported. The Korean war offered an opportunity to obtain such studies, and the results have been interesting, particularly as far as they involve late joint changes.

II. CLINICAL MATERIAL

The material for this study is based on 100 enlisted men who incurred frostbite in Korea between 6 December 1950 and 5 March 1951. The clinical findings in these patients are included in a report by Orr and Fainer (6). The importance of the racial background for the occurrence of the cold injuries has been stressed by these authors. Forty-one per cent of the soldiers in this study were Negro, a considerably higher percentage than would correspond to the number of exposed Negro troops.

The majority of the patients had suffered severe cold injuries as indicated by the degree of soft tissue damage. Orr's four degrees of frostbite were used for classification of the soft tissue injury. The first degree consisted of erythema, edema and superficial desquamation only. The second degree showed vesiculation of partial skin thickness. The third degree involved the full thickness of skin extending into varying depths of subcutaneous tissue with or without vesiculation. The fourth degree resulted in damage of the deep structures down to and usually including bone. Many patients had a mixture of different degrees of involvement on different portions of their body at the same time. Classified according to the most severe degree, the totals show 3 patients with first degree frostbite, 10 with second degree, 70 with third degree and 17 with fourth degree frostbite.

There were 64 who had clinical involvement of a portion or all of both feet only, 2 with involvement of both hands only. There were 9 with frostbite only of the right foot, 16 with involvement of the left foot only, and 1 with involvement of the right hand only -- the remaining 8 had various combinations of frostbite of the hands and feet. The overall total showed clinical frostbite of a portion, or all, of the following areas: 80% - right foot, 86% - left foot, 7% - right hand, and 8% - left hand.

Where there was a marked difference between the appearance of one digit and the remainder of the hand or foot, they showed the following distribution:

<u>Right Foot</u>		<u>Left Foot</u>		<u>Right Hand</u>		<u>Left Hand</u>	
1st toe	36	1st toe	38	Thumb	1	8	
2nd toe	8	2nd toe	6	Index	1	(Not class-	
3rd toe	0	3rd toe	1	Middle	2	ified as to	
4th toe	0	4th toe	1	Ring	2	digits)	
5th toe	2	5th toe	6	Little	1		
Right Heel	1	Left Heel	3				

III. ROENTGENOLOGICAL EXAMINATIONS AND FINDINGS

The majority of the 100 patients on which the study is based had early roentgenological studies, the shortest interval between exposure and X-rays being 9 days, the longest being 110 days. They had repeated examinations thereafter, an average of more than three later examinations. The number of those which were X-rayed naturally decreased as time went on, but of the original 100 patients, 62 were X-rayed eight months post-frostbite, 47 one year post-frostbite and 38 fifteen months post-frostbite.

In 36 patients no bone abnormality was found at any time. The other patients showed some alterations in the roentgenological appearance of their bones. They were classified into four groups.

Group A showed osteoporosis.

Group B showed acromutilation (mutilation of terminal phalanges due to exposed bone).

Group C showed late changes in the bones close to the joints of feet or hands.

Group D showed other bone changes.

A. Frostbite Cases Showing No Roentgenological Changes

Thirty-six soldiers showed no roentgenological abnormality. This group included a number of cases with marked mummification of the soft tissues. The absence of roentgenological changes in the presence of mummification has been stressed by many previous authors. It is easily explained by the absence of metabolic changes in the bone which is severed from its blood supply. (See Fig. 1).

B. GROUP A. (Osteoporosis)

The osteoporosis, although noticeable in 58 exposed, was not marked with the exception of one case (See Fig. 2). When osteoporosis occurred it was usually present in the fourth to the tenth week. The evaluation of smaller degrees of osteoporosis is extremely difficult under the best technical circumstances but even more so in a series such as this where the examinations were performed in different X-ray departments. It is of interest, however, to note the almost complete absence of a severe degree of osteoporosis during any stage of this observation period and the absence of any osteoporosis after six months following injury. This is in contradistinction to various statements in the literature (Oehlecker, (5) Ruckenstein, (7)).

C. GROUP B. Acromutilation (Bone changes following exposure to air)

This group includes nine patients. Almost all lesions in this group involved the big toes. The second toe was involved in two instances and the heel in one of the cases.

When studying late films of patients following frostbite one at times sees mutilation of the tips of the extremities, particularly involving the tufts of the great toes. The literature quotes these deformities as being directly caused by exposure to cold. An analysis of the cases of this study shows that in most instances the overlying soft tissue had been damaged to such a degree that the bone had become exposed to air and either had become destroyed by osteomyelitis or had been subsequently removed surgically (See Fig. 3). Actual exposed bone could be seen in most instances on the films. In the other cases ulceration of the soft tissues, visible on photographs, made exposure of the underlying bone appear likely, even though actual surgical removal of a sequestrum was not always mentioned in the record. The material did not contain a single case in which direct influence of the cold on the bone underneath intact skin could be pointed to as the cause of the mutilation of the phalangeal tips.

D. GROUP C. (Late changes close to joints of hands and feet)
(See Figs. 4-9)

This group proved to be of particular interest. The lesions consisted of small, usually round punched out areas of decreased density which later became surrounded frequently by a margin of dense bone. The defects in most instances opened into the joint space. Usually, although not always, they were present near the edge of the joint, approximately in the area of the attachment of the joint capsule. In a few instances the defects appeared to be separated by a narrow band of normal bone from the joint surface. It is possible that a different view might have shown a direct opening of the apparently subarticular defect into the joint space. Narrowing of the joint space occurred only in a few markedly afflicted joints.

Such juxta-articular bone changes were found in 7 soldiers. The hands were involved only in 2 of them. One of these also had involvement of joints of the feet, the other did not. A single foot was involved in 3, while 3 soldiers had involvement in both feet. A total of 25 joints were seen afflicted in the 7 soldiers. They included nine proximal and seven distal interphalangeal joints of the toes, as well as three metatarsal phalangeal joints. The hands showed involvement of four proximal and two distal interphalangeal joints. The toe most commonly involved was the fifth toe (8 joints in 6 fifth toes). The joints of the great toe which showed clinically an overwhelming preponderance of frostbite injury were involved only in five instances. This discrepancy is striking.

An attempt to correlate the joint changes with the clinical manifestations of frostbite showed in many instances that the involved joint belonged to a toe or a finger which had clinical evidence of frostbite injury. Quite frequently, however, the digit with the most marked soft tissue damage showed no joint change while other digits with less soft tissue damage in the same patient did. Third degree frostbite was present in only five of the involved digits; in others the involvement was that of second or first degree. It is also interesting to note that Orr and Fainer (6) saw a late disturbance of sweat (hyperhidrosis) in both feet when only one foot had shown initially clinical evidence of frostbite. This would indicate that cold can produce tissue alterations without gross evidence initially of even a first degree frostbite.

The joint changes did not become noticeable until several months after the cold exposure. With the exception of one case in which minor changes were first seen three months post-frostbite and

another one where they were seen five months post-frostbite, the joint changes were not seen until eight months post-frostbite. Since these roentgenological changes, with two exceptions, were not noticed before the eighth month, it seems worthwhile to point out that of the original 100 soldiers only 62 had re-examinations at such a late date. The seven soldiers showing these particular bone changes represent 11.3% of this group of 62.

There was a gap in the roentgenological observation of most of the cases between the third and eighth month. It is likely that the majority of the joint lesions would have been visible some time between the third and eighth month if roentgenological examinations had been done during this period.

No joint normal at the eighth month examination showed later evidence of pathology, at least not in the relatively short observation period. There was, however, a definite increase in the degree of joint involvement between the eighth to the twelfth month period in some of the cases. Observations beyond the twelfth month are incomplete. When done, a fifteenth month examination showed no further progress in most instances, although there was some progress of the disease in one of the joints. Later observations in this group are obviously desirable and will be attempted.

For completeness sake, it should be mentioned that in a few instances small juxta-articular defects which simulated the above bone changes were seen on early films. They were considered as existing prior to frostbite since they had dense margins and did not change during further observation.

Of the seven soldiers with joint changes post-frostbite five were Negroes and two were white.

The absence of late clinical symptoms in regard to the involved joints was striking in most instances. In only one case (See Fig. 6) was there any restriction of motion of the involved joint.

E. GROUP D. (Other bone changes)

This group comprises four cases which could not be readily classified with the other groups. Two of the cases of this group had periostitis. In one of them, a 5th metatarsal and the corresponding proximal phalanx showed periosteal new bone formation (See Fig. 10). The head of this phalanx showed suggestive evidence of osteomyelitis. Clinically, third degree frostbite was present. The other case showed periosteal new bone formation of the proximal phalanx of the 4th toe, and of the 5th metatarsal bone. Third degree frostbite involved all toes.

The third case showed early disintegration of the middle phalanx of the fifth toes in an area of mummification. This may have been osteomyelitis but definite proof is missing. Finally, the fourth case showed a defect in the terminal tuft of a second toe without evidence of exposure of bone to air. The patient did have an ulcer over the involved area. On none of the films available does the bone reach the surface. For that reason, the case could not be classified in Group B, although it most likely belongs in that group.

IV. DISCUSSION

The roentgen examination of the skeleton shows no demonstrable abnormality immediately following frostbite of any degree, and is therefore of no clinical help at that stage. Later, however, bone changes may occur. They are at times of clinical significance.

The most common abnormality in the bone is the presence of osteoporosis. In contradistinction to reports in the literature the osteoporosis in these cases was not severe. It was of short duration only and offered no clinical problem. On the other hand, the presence or absence of osteoporosis may at times be useful as an indicator of the vitality of the underlying bone. The bone which shows evidence of osteoporosis obviously is viable with preserved vascularization and metabolism. On the other hand, absence of osteoporosis in phalanges, with the presence of osteoporosis in metatarsal and tarsal bones, is suggestive of absence of circulation in the involved phalanges.

The presence of periosteal new bone formation occurred in a few instances. Oehlecker (5) has pointed out that this new bone formation occurs particularly in a phalanx just proximal to an area of marked mummification. In the present cases it has been seen in two instances, just proximal to the area of maximal cold injury. Similar to osteoporosis, the presence of periostitis is an indicator of viability. The demonstration of periostitis may therefore be of clinical significance in a borderline case.

Of particular interest are the late bone changes which were noted close to the joint surfaces in 7 of the cases. Loehr (2) apparently was the first one to describe such a case. v. Tempsky (9) and Oehlecker (5) each described one case. All three concerned frostbite of the hands. Ruckenstein states that he has seen similar changes in the feet of skiers. He does not give any details in regard to the number and types of patients and publishes no roentgenograms. The joint changes in three cases were observed between six months and four years following frostbite (8 months in most of the cases of this study). There

were clinical symptoms in all three cases of the literature. Loehr's case showed swelling and limitation of motion in both hands after six and nine months respectively, which disappeared in a few weeks after the onset in one hand. v. Tempsky's case had limitation of motion and pain with motion, while Oehlecker's case showed restriction of motion of the involved joints. With the exception of one of the cases of the present study which showed limitation of motion of the involved joints of the fifth toe (See Fig. 6) the involved joints appeared normal to clinical observation. This difference from the observations of the previous authors, is probably primarily due to the fact that their cases involved hands, and the present cases mostly feet. It is also possible that the observation period in these cases is still too short and that some clinical symptoms will appear later.

The etiology of these juxta-articular bone changes is obscure. Direct influence of the cold on the bones appears excluded by the fact that the overlying soft tissues showed in some instances very little evidence of frostbite. It is very tempting to postulate vascular changes, either anatomical or functional, as the cause for the late bone changes. Purely radiologically, the lesions are similar to those frequently seen in rheumatoid and occasionally seen in degenerative arthritis of the hands and feet. Injury to the joint cartilage may be the common denominator in all three conditions. Histological and experimental studies are obviously needed for further study of this problem. Its solution may not be without significance for the basic problem of cold injury.

V. SUMMARY

1. The early and late (up to fifteen months) bone changes occurring in a carefully observed group of 100 soldiers with frostbite are described.
2. In 36 cases no bone abnormalities were found at any time. This group includes most cases with mummification of toes.
3. Osteoporosis was seen in 58 instances. It was always transient and usually not severe. Osteoporosis, if present, is evidence of a viable bone.
4. Acromutilation (mutilation of terminal portions of bone, usually terminal phalanges) occurred in ten instances. It could be traced to loss of overlying tissues, exposure to air, and usually subsequent surgical removal of the exposed fragment.

5. Late bone changes close to joints of hands and feet are lesions of particular interest. They occurred in 7 soldiers out of a group of 62 which had at least an eight months observation period. The changes consisted in defects close to the involved joints, usually at the joint edge. With two exceptions the changes were not noticed until eight months post-frostbite. The lesions frequently increased in size during the first year post-frostbite but no new lesions were seen after the eight months examination.

There was no correlation between the degree of the soft tissue injury and the joint changes. In some instances the roentgenologically involved digits had shown clinically not more than first degree frostbite.

With one exception the involved joints showed no late clinical abnormality.

6. The arthritic changes are of theoretical interest. Their further study may throw some light on the etiology of frost injury in general.

7. Frostbite is an additional etiological factor in the type of arthritis presenting small subarticular punched out areas in the bone close to the joint.

When lesions of this type are encountered frostbite must be considered an etiological factor. The significance this may have in ascertaining disability in veterans is obvious.

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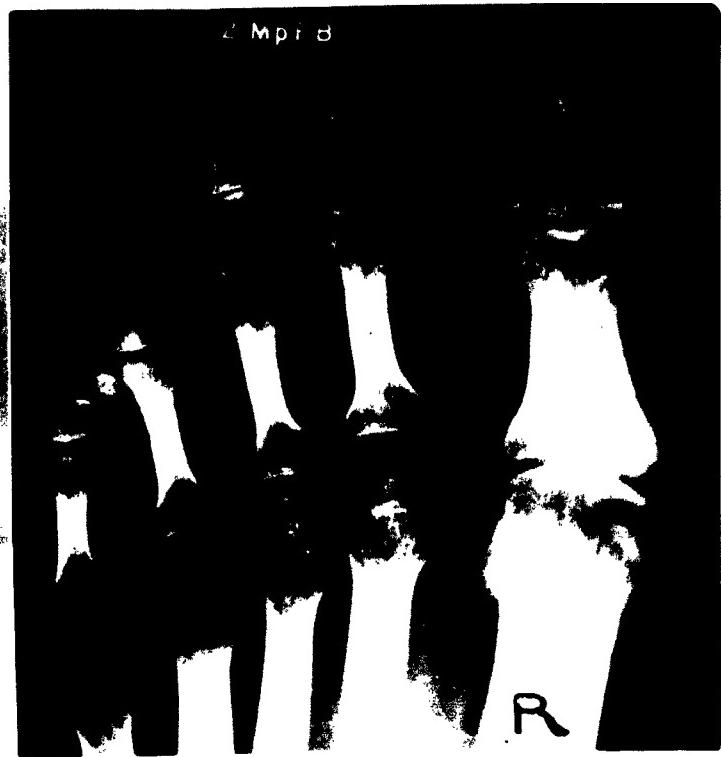
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LEGENDS

Fig. 1 ABSENCE OF OSTEOPOROSIS IN THE MUMMIFIED TOES OF THE RIGHT FOOT. See osteoporosis of the toes of the left foot, particularly the great toe - and also of the metatarsals and the bases of the second to fifth proximal phalanges of the right foot. The photograph of the feet and the roentgenograms were taken on approximately the same day, two months following the frostbite. Clinically: 4th degree frostbite of toes of right foot.



RIGHT FOOT



LEFT FOOT

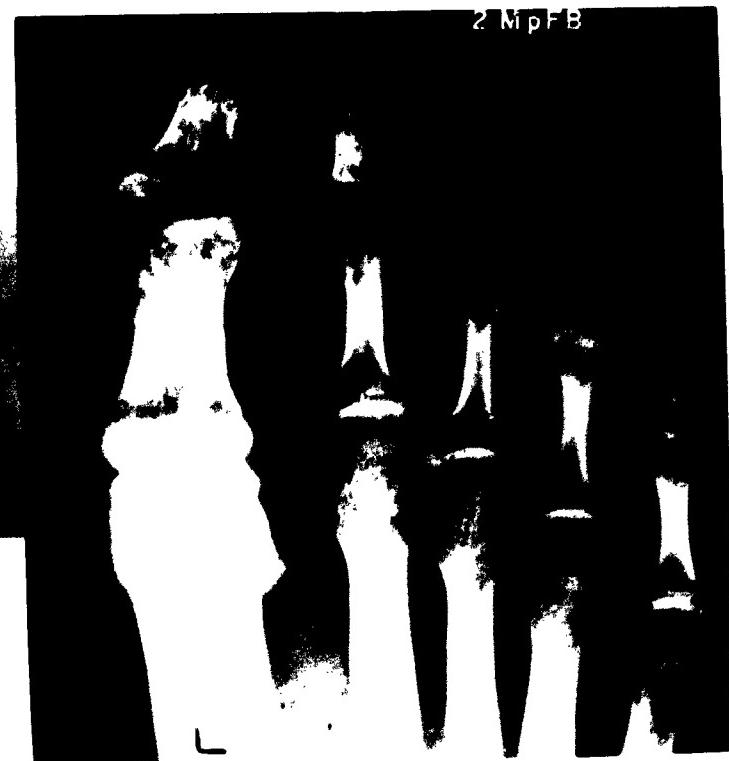


FIG. 1

Fig. 2 **BILATERAL OSTEOPOROSIS.** This was the only case in the series who showed a fairly marked degree of osteoporosis. Films were taken 45 days post-frostbite. The earliest changes were seen 24 days post-frostbite. Some osteoporosis was still present on films taken four months post-frostbite. Films taken eight months post-frostbite showed no abnormality of the bones.
Clinically: Third degree frostbite of both feet, involving particularly the great toes.

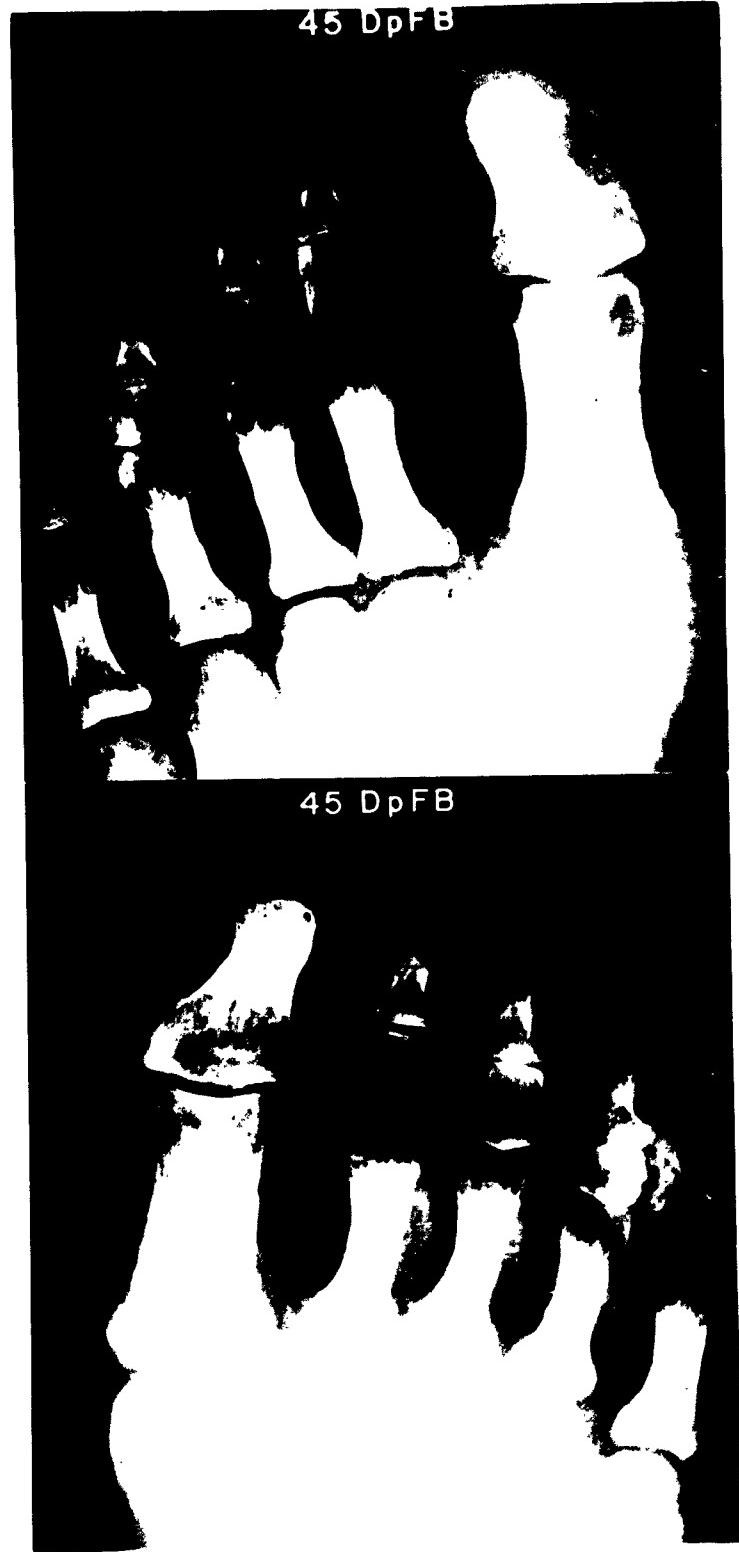


FIG. 2

Fig. 3 MUTILATION OF THE TIP OF THE RIGHT GREAT TOE. Roentgenograms taken 43, 55 and 71 days post-frostbite. The first roentgenogram shows a soft tissue defect reaching the bone. The second roentgenogram shows formation of a sequestrum which apparently had been removed before the last film was taken.
Clinically: Third degree frostbite with ulceration of the tip of the great toe and visible exposure of bone.

Fig. 4 DEVELOPMENT OF LATE BONE CHANGES IN LEFT FIFTH FINGER. No abnormality is seen three months post-frostbite. Definite changes are seen eight months post-frostbite, which have increased considerably sixteen months post-frostbite. The patient had lost his gloves while under enemy fire and was exposed to the cold with his gloves off for nine hours. He developed third degree frostbite of both hands. The proximal phalanges of the left hand revealed a bullous cuff. The right hand showed similar changes, not quite as marked.
Roentgenologically there were additional late changes involving the second and fourth fingers of the left and the fifth finger of the right hand - not as marked as those seen in the illustrated left fifth finger.

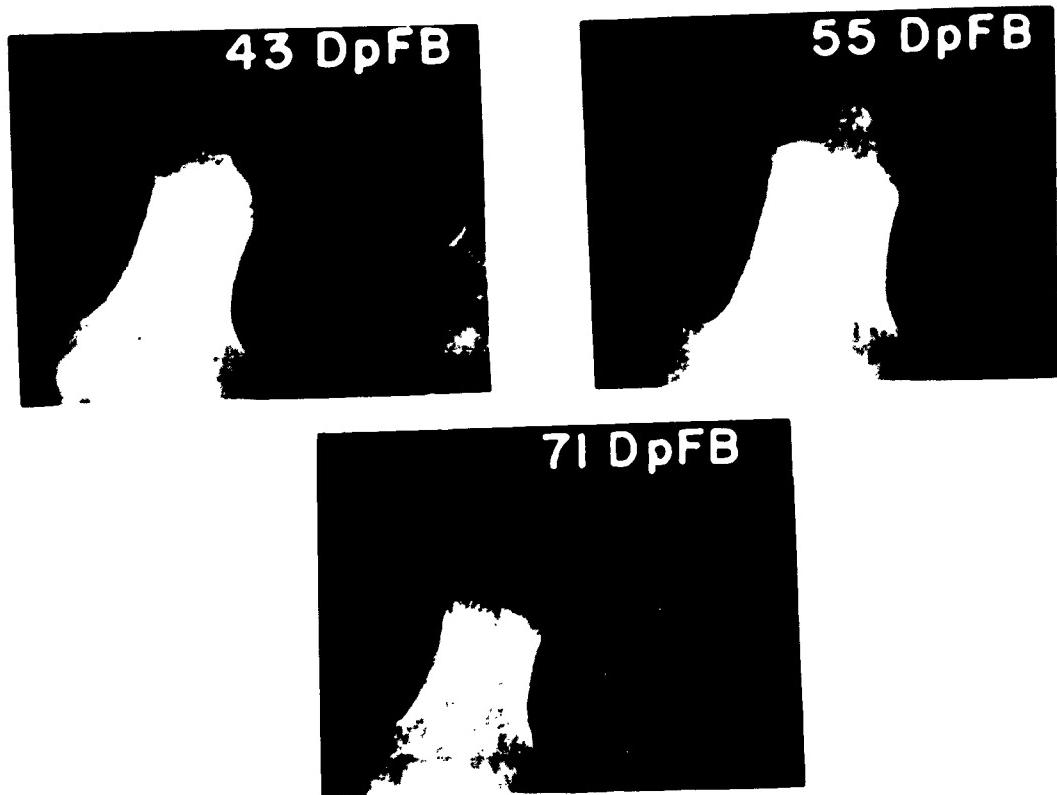


FIG. 3

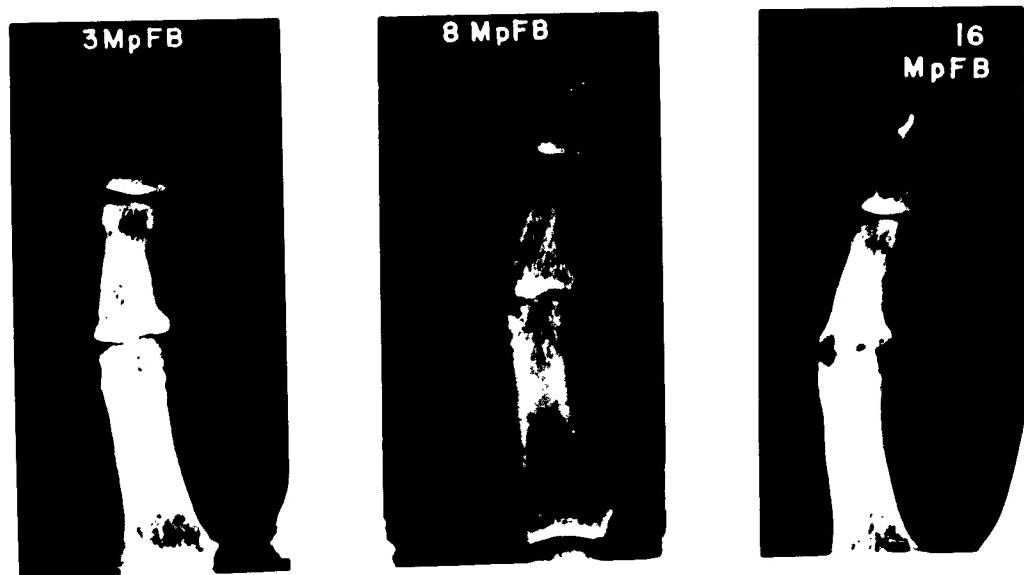


FIG. 4

Fig. 5 DEVELOPMENT OF LATE JOINT CHANGES. No abnormality three months post-frostbite. Definite defects eight months post-frostbite which have increased four months later. The fourth and fifth toes of the same foot also showed similar joint changes. (See Figure 6). Third degree frostbite of the illustrated right first toe.

Fig. 6 DEVELOPMENT OF LATE JOINT CHANGES involving both interphalangeal joints of the right fifth toe. (The same patient as Figure 5.) No changes are seen three months post-frostbite. Definite changes are established eight months post-frostbite. There is only slight increase of the deformity four months later.
Clinically: First degree frostbite of this toe.

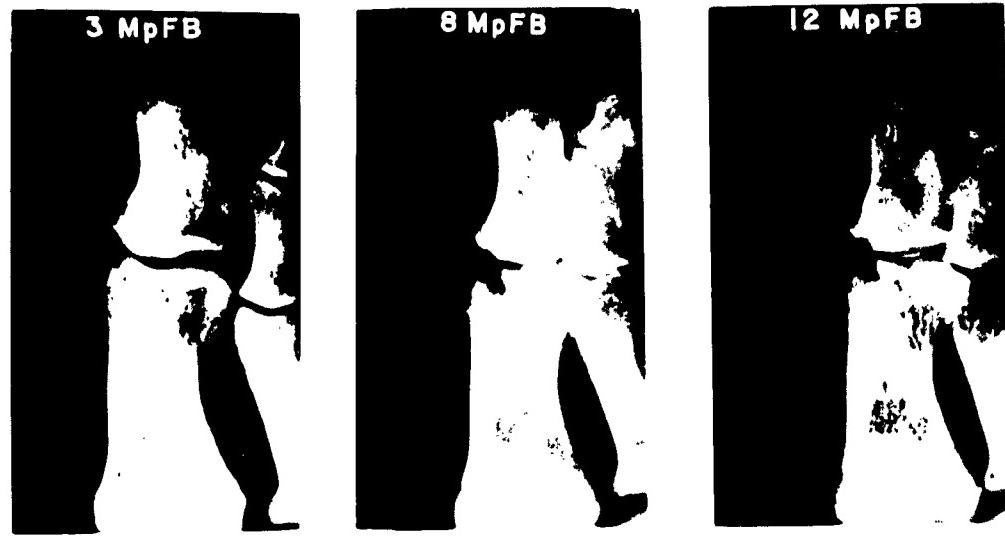


FIG. 5



FIG. 6

- Fig. 7** LATE DEVELOPMENT OF JOINT CHANGES IN LEFT FIFTH TOE. No abnormality three months post-frostbite. Definite defect five months post-frostbite with considerable increase of the deformity seven months after frostbite.
Clinically: 3rd degree frostbite.
- Fig. 8** DEVELOPMENT OF LATE ARTICULAR BONE CHANGES OF RIGHT FIFTH TOE. No abnormality four months post-frostbite. Round defect with surrounding bone reaction nine months post-frostbite without any change seven months later. Although no connection with the joint is visible on these films, it is possible that a different projection might have shown such a connection.
Clinically: First degree frostbite of the left foot including this toe.

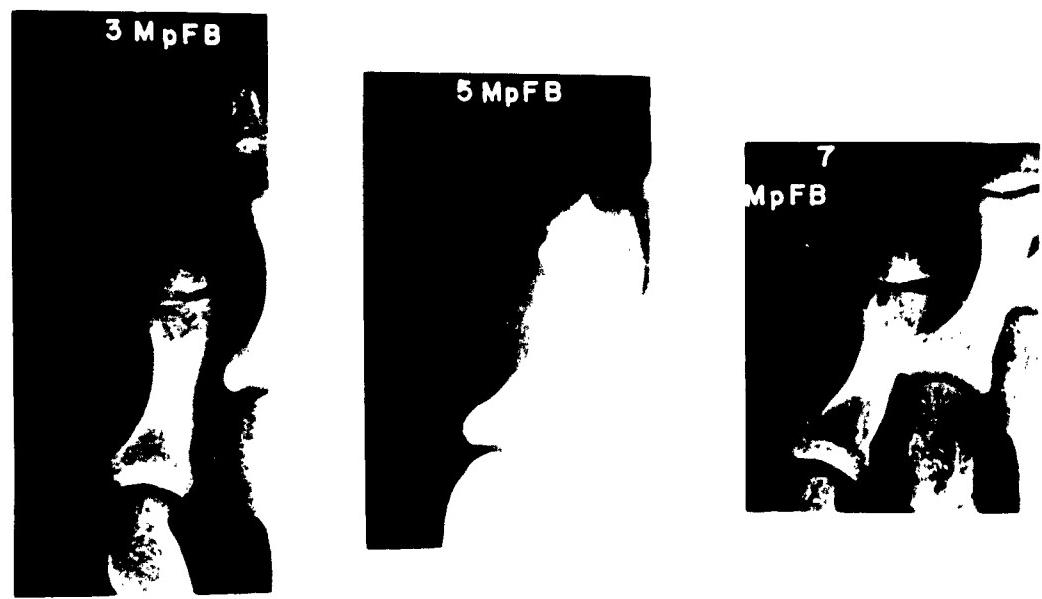


FIG. 7



FIG. 8

Fig. 9

DEVELOPMENT OF LATE JUXTA-ARTICULAR BONE CHANGES in second, third and fifth toes of right foot. A roentgenogram two months post-frostbite shows osteoporosis but no joint changes. A roentgenogram fifteen months post-frostbite shows sharply defined defects in three toes. Some of them are definitely connected with the joint surface. The others might be, in a different projection.

Clinically: First degree frostbite of the greater portion of the right foot, blister formation only over the distal phalanx of the third toe.

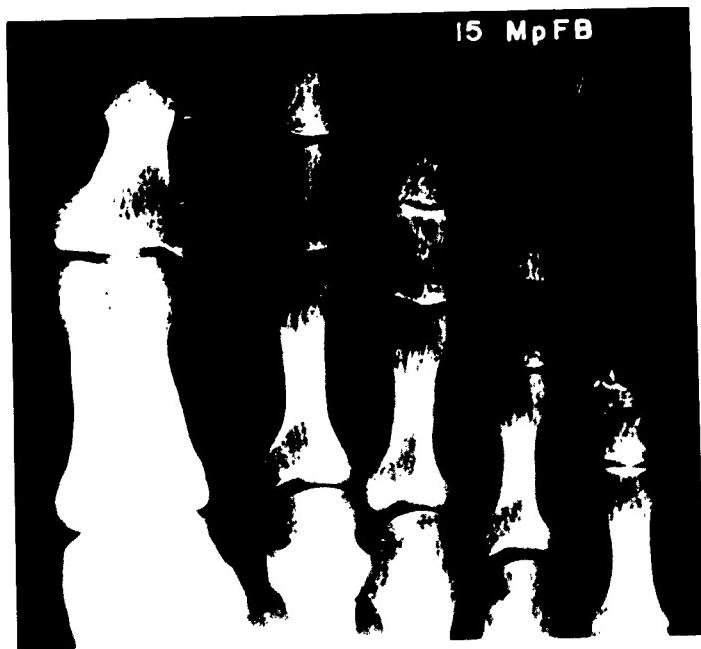
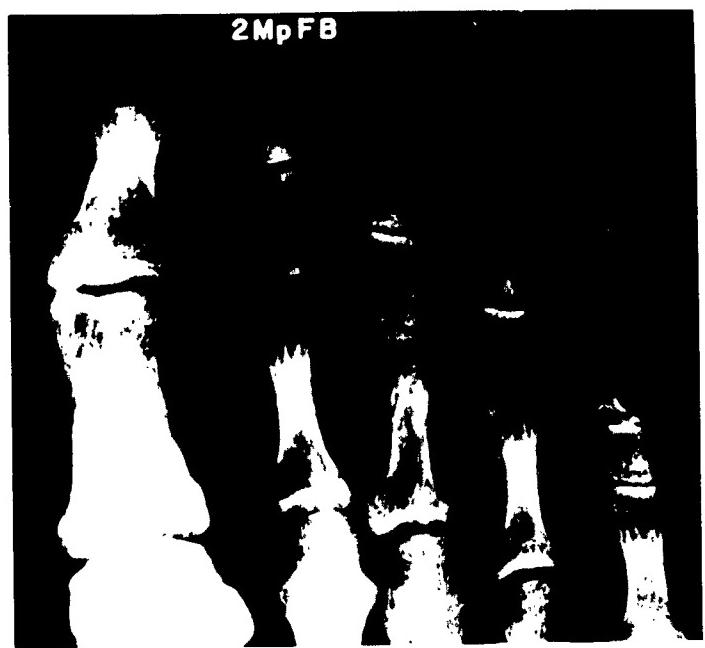


FIG. 9

Fig. 10 PERIOSTEAL NEW BONE FORMATION of the left fifth metatarsal and proximal phalanx two months, and four months, post-frostbite. There is suggestive evidence of osteomyelitis in the head of the proximal phalanx two months post-frostbite, which is no longer visible four months post-frostbite. The terminal phalanx apparently was partially mummified and has been partially removed on the second roentgenogram.
Clinically: Third degree frostbite of the left fifth toe which extends into extensive bulla over the lateral aspect of the feet.

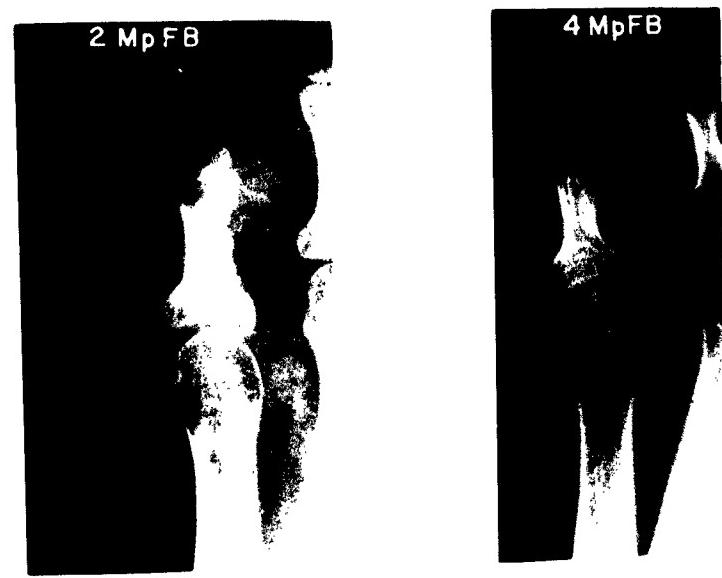


FIG. 10